

Characteristics of 6.X-nm Beyond EUV sources

Monday,
Oct. 1st

Takeshi Higashiguchi¹, Takamitsu Otsuka¹, Thomas Cummins², Colm O'Gorman², Bowen Li²,
Deirdre Kilbane², Padraig Dunne², Gerry O'Sullivan², Weihua Jiang³, and Akira Endo⁴

¹Utsunomiya University, ²UCD, ³Nagaoka University of Technology, ⁴HiLASE Project, Institute of Physics AS

E-mail: higashi@cc.utsunomiya-u.ac.jp

1. Introduction

Extreme-ultraviolet (EUV) lithography at 13.5 nm is expected to be introduced in high-volume manufacturing of integrated circuits (ICs) having node sizes of 32 nm or less. Lithography at this wavelength is capable of reaching feature sizes below 10 nm. Beyond that, switching to a shorter wavelength of around 6.X nm, while maintaining or increasing throughput in the lithography system, would improve resolution by a further factor of two and extend the technology to feature sizes of a few nm. The choice of **6.X nm** is based on the availability of suitable reflective optics; EUV emission at this wavelength may be coupled with a La/B₂C or Mo/B₂C multilayer mirror with a reflectivity of 40-50%. Recently, a reflection coefficient of about 80% for these multilayers was shown to be feasible in a theoretical study.

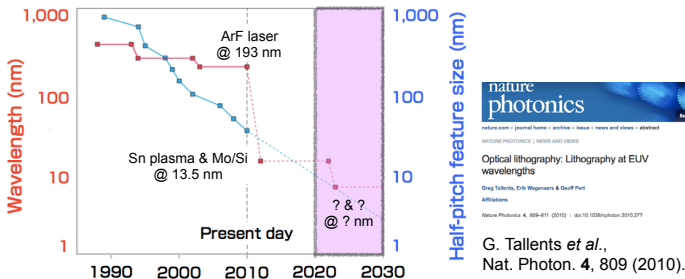
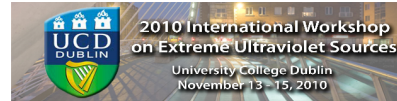
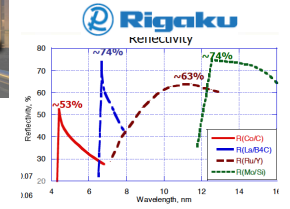


Fig. 1. Over the past twenty years, the field of lithography has seen a dramatic reduction in both the half-pitch feature size and the wavelengths used, but at very different rates. A significant drop in wavelength is now needed if Moore's law is to be maintained. The dotted lines show how the wavelength and feature size are expected to change over the next twenty years.



From ASML presentation shows as follows:

- (1) extensive (beyond 8 nm@~2017)
- (2) **6.X nm choice: Best transmission & Easier Manufacturing**
- (3) Source: New fuel is needed (Gd and/or Tb, other???)
- (4) $R \sim 80\%$ (cal), $R \sim 40\%$ (exp)@La/B₂C MLM
- (5) **Optical throughput for 6.7 nm & 13.5 nm is comparable!!!**



2. Gd and Tb plasmas for 6.X-nm BEUV

We observed the 6.X-nm BEUV spectra of laser-produced Gd and Tb plasmas. Their emission has similar spectral structures as Sn and Xe for 13.5-nm EUV sources.

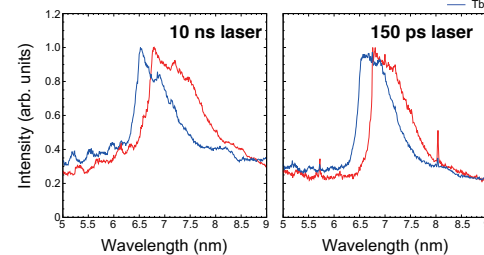


Fig. 2. Spectral comparison Gd with Tb plasmas by the 1-mm laser pulse irradiation at pulse durations of 10 ns (left) and 150 ps (right), respectively.

3. Fundamental characteristics of Gd and Tb plasmas for 6.X-nm BEUV sources

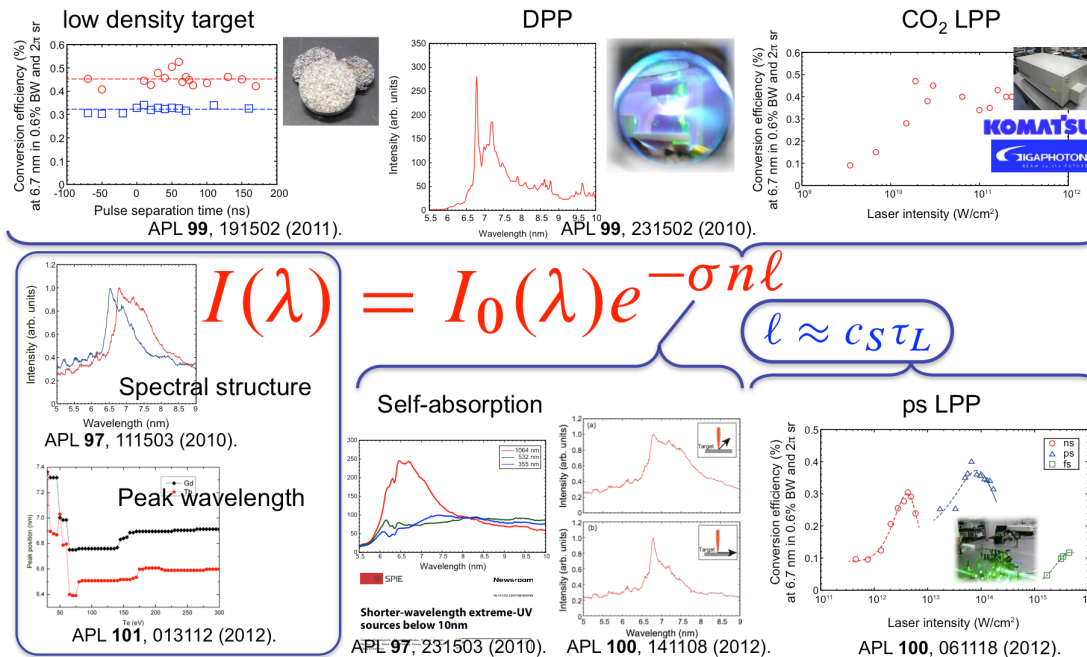


Fig. 3. Fundamental characteristics of Gd and Tb plasmas for efficient 6.X-nm BEUV sources.

For efficient source achievement, we should produce **100-eV, low density plasmas**. Exactly analogous to CO₂ laser-produced Sn plasmas for 13.5-nm. In the case of CO₂ laser plasmas, the optimum laser intensity is estimated to be $2 \times 10^{11} \text{ W/cm}^2$.

4. Summary

We have characterized the fundamental properties of the 6.X-nm BEUV emission from the laser- & discharge-produced Gd & Tb plasmas. According to various characteristics we conclude that 100-eV low-density plasmas are optimum, and the behavior is analogous to CO₂ laser-produced Sn plasmas for 13.5 nm EUV sources. In the case of CO₂ laser plasmas of Gd, the optimum laser intensity is estimated to be $2 \times 10^{11} \text{ W/cm}^2$.

Acknowledgements

Part of this work was performed under the auspices of MEXT (Ministry of Education, Culture, Science and Technology, Japan). One of the authors (T.H.) also acknowledges support from The Canon Foundation and Research Grant (Basic Research) on TEPCO Memorial Foundation. We also are grateful to the Komatsu Ltd. and Gigaphoton Inc. for providing the picosecond laser system. The UCD group acknowledges support from Science Foundation Ireland under grant 07/IN/11771



Optical lithography: Lithography at EUV wavelengths
Gig. Talents, S. H. Wagners & G. P. P. P.
Affiliations
Nature Photonics 4, 808-811 (2010) | doi:10.1038/nphoton.2010.277

Shorter-wavelength extreme-UV sources below 10nm

